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Defence R&D Canada – Toronto
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Abstract

Current oil and gas exploration requirements to exploit deeper water change the method of oil extraction. Floating Production Storage and Off-loading (FPSO) vessels are increasingly being used to operate in these fields where the environment can be very extreme. The Petro Canada Terra Nova Floating, Production, Storage, Offshore vessel (FPSO) is the first of its kind built for operations on the Grand Banks at the Terra Nova field and is the first to operate in Canadian waters. The crew on these vessels is expected to operate for as long as possible under extreme weather conditions within certain safety margins. Seasickness and its after-effects, motion-induced fatigue and motion-induced interruptions remain a potential threat to crewmembers at sea. Understanding the incidence, severity and the effects of seasickness on performance, can improve effective scheduling and task assignment. This survey attempts to (1) define the incidence and severity of the symptom complex of seasickness, motion-induced fatigue and task performance problems encountered on the Terra Nova FPSO vessel and (2) to examine correlations (if any) between FPSO vessel motions, seasickness, motion-induced fatigue and task performance, towards the development of recommendations to provide operations guidance to ameliorate seasickness and improve comfort and performance in the environment described above. A questionnaire-based survey of motion effects including sleep problems, symptoms and severity of seasickness and task performance was administered at various times during 3-week offshore shifts. Ship motion data provided for this analysis was based on data gathered from the helideck (at the bow of the FPSO vessel) motion analysis and was provided by the radio operator from the FPSO Offshore Installation Office. Based on 911 questionnaires returned, problems reported for sleep disturbance and motion sickness symptoms were slight to moderate. However, the correlation between sleep disturbance and ship motion was relatively high. January has the highest correlations among pitch, roll and heave motion with complaints of seasickness. Task performance problems such as loss of concentration, decision-making and memory disorders and task completion problems were observed. There appeared to be no apparent habituation among subjects who participated in more than 2 shifts offshore. It is apparent that the number of safety, health and performance issues increases with the deterioration of weather condition. This data serves as a preliminary assessment; direct measurement of the FPSO vessel motion and a longitudinal study through the winter months is required to substantiate our findings.

Résumé

De nos jours, l'exploitation pétrolière en mer se fait à des profondeurs de plus en plus grandes et les méthodes d'exploration ont changé, notamment avec l'utilisation des navires de production et de stockage de pétrole au large ou FPSO (de l'anglais *Floating Production Storage and Off-loading*) qui exploitent des champs pétrolifères où les conditions environnementales peuvent être extrêmes. Le navire FPSO Terra Nova de Petro Canada est le premier navire du genre à être construit pour l'exploitation du champ pétrolifère Terra Nova des Grands bancs et le premier à naviguer dans les eaux canadiennes. On attend des équipages de ces navires qu'ils travaillent aussi longtemps que possible dans des conditions climatiques extrêmes à l'intérieur d'une certaine marge de sécurité. Le mal de mer et ses effets secondaires, la fatigue attribuable au mouvement et les interruptions causées par les mouvements du navire représentent des menaces potentielles pour ces équipages. Une meilleure compréhension de la fréquence, de la gravité et des conséquences du mal de mer sur le rendement devrait permettre de planifier et d'assigner les tâches plus efficacement. La présente étude a pour objet (1) de déterminer la fréquence et la gravité de l'ensemble de symptômes associés au mal de mer, à la fatigue due au mouvement et aux problèmes d'exécution des tâches rencontrés sur le FPSO Terra Nova et (2) d'examiner les corrélations (le cas échéant) entre les mouvements des FPSO, le mal de mer, la fatigue due au mouvement et l'exécution des tâches, en vue de préparer une série de recommandations qui pourraient servir de guide dans l'élaboration d'un plan d'opérations visant à réduire les effets du mal de mer et à améliorer le confort et le rendement des équipages dans les conditions environnementales susmentionnées. Un sondage basé sur un questionnaire portant sur les effets du mouvement sur le sommeil, les symptômes et la gravité du mal de mer et l'exécution des tâches a été effectué à divers moments dans le cours d'une période de travail de 3 semaines en mer. Les données sur les mouvements du navire recueillis pour cette analyse reposent sur une série de relevés faits sur la plate-forme d'appontage de l'hélicoptère (à l'avant du FPSO) et transmis par l'opérateur radio aux bureaux des opérations offshore de la compagnie. À partir des 911 questionnaires retournés, on a appris que les problèmes associés aux troubles de sommeil et aux symptômes du mal des transports pouvaient être qualifiés de légers à modérés. Par contre, la corrélation entre les troubles de sommeil et les mouvements du navire était relativement élevée. Le mois de janvier a connu le plus important taux de corrélation entre les mouvements du navire (tangage, roulis et pilonnement) et les plaintes associées au mal de mer. On a relevé plusieurs problèmes d'exécution et de réalisation des tâches, notamment au niveau de la perte de concentration, de l'indécision et des troubles de mémoire. Il ne semble pas exister de phénomène d'accoutumance parmi les sujets qui ont participé à plus de deux périodes de travail en mer. Il est apparent que le nombre de questions liées à la sécurité, à la santé et au rendement augmente quand les conditions climatiques se détériorent. L'analyse de ces données tient lieu d'évaluation préliminaire; il faudra prendre d'autres relevés de mouvements directement sur le FPSO et faire une étude longitudinale échelonnée sur tout un hiver pour vérifier nos conclusions.

Executive summary

The Petro Canada Terra Nova Floating, Production, Storage, Offshore vessel (FPSO) is the first of its kind built for operations on the Grand Banks at the Terra Nova field. It is the first of its kind to operate in Canadian waters. The FPSO vessel is tethered to the oil well head by several flexible couplings. Therefore, unlike fixed installation oil drilling platforms, a common feature of FPSO vessel operation is that it will be subjected to severe wave motion at sea, and consequently it needs to be able to operate for as long as possible in severe conditions. As a result, it is expected that crewmembers living and working aboard the FPSO vessel will be exposed to more severe weather and motion (especially during the winter months) than those on conventional fixed installation platforms. This survey study is based on a series of questions attempting to investigate if seasickness is a problem and whether certain ship motions affect sleep, mental and physical performance on-board. Sensors mounted at the bow of the vessel provided the ship motion data. Based on 911 returned questionnaires, it was found that the incidence and severity ranged from slight to moderate. It is apparent that the number of safety, health and performance issues increases with the deterioration of weather conditions. Further studies for extended periods of time, with more participants are required to verify these findings.

Cheung, B., Brooks, C.J., Hofer, K. 2002. Assessment of motion effects on the FPSO (Floating, Production, Storage and Offloading) vessel Terra Nova. DRDC Toronto TR 2002-144 Defence R&D Canada – Canada.

Sommaire

Le navire de production et de stockage de pétrole au large ou FPSO (de l'anglais *Floating Production Storage and Off-loading*) Terra Nova de Petro Canada est le premier navire du genre à être construit pour l'exploitation du champ pétrolifère Terra Nova des Grands bancs et le premier à naviguer dans les eaux canadiennes. Il est amarré à la tête du puits du gisement par plusieurs accouplements flexibles. Donc, contrairement aux plates-formes de forage fixes, les FPSO sont soumis à l'action souvent violente des vagues et, en conséquence, leurs équipages doivent être aptes à travailler pendant de longues périodes dans les conditions climatiques extrêmes. On s'attend donc à ce que les personnes qui vivent et travaillent à bord des FPSO soient exposées à des conditions météo plus mauvaises et à des mouvements plus violents (surtout pendant l'hiver) que ceux qui travaillent sur des plates-formes fixes. La présente étude repose sur une série de questions qui visaient à savoir si le mal de mer représentait un problème important ou si certains mouvements du navire avaient une incidence sur le sommeil, le rendement mental et la condition physique à bord. Des capteurs montés sur l'avant du navire ont fourni des données sur les mouvements du navire. À partir des 911 questionnaires retournés, on a pu constater que la fréquence et la gravité des problèmes variaient de légers à modérés. Il est apparent que le nombre de questions liées à la sécurité, à la santé et au rendement augmente quand les conditions climatiques se détériorent. Il faudra prendre d'autres relevés de mouvements directement sur le FPSO et faire une étude longitudinale échelonnée sur tout un hiver pour vérifier nos conclusions.

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Introduction

The Petro Canada Terra Nova FPSO (Floating, Production, Storage, Offloading) vessel is the first of its kind built for operations on the Grand Banks at the Terra Nova field for offshore gas and oil production. It is also the first to operate in Canadian waters. This vessel is designed specifically for environmental conditions offshore of Newfoundland, with a reinforced double hull to protect it from ice. It has the largest quick-release turret system for oil extraction in the world. The FPSO vessel tethered to the oil well head by several flexible couplings and yet being exposed to wind and waves is stabilized and positioned by a complex controlled system of trimming and thrusting. Therefore, unlike semi-submersible or fixed installation oil drilling platforms, a common feature of FPSO vessel operation is that they will be subjected to drastic wave motion at sea, and consequently they need to be able to operate for as long as possible in severe conditions. The FPSO vessel will not be required to depart from its anchoring station in any but the most extreme weather conditions. As a result, it is expected that crewmembers living and working aboard the FPSO vessel will be exposed to more severe weather and motion (especially during the winter months) than those on conventional fixed installation platforms. Furthermore, personnel may have to remain on the vessel as the motion becomes severe and when ship-to-ship transfers or evacuation by helicopter may not be possible. Unlike other marine vessels, the majority of the crews are not mariners per se, but personnel who traditionally work on fixed land-based oilrigs and installations. Therefore, they might not have been self-selected out occupationally through seasickness.

Motion-induced fatigue, motion-induced interruption (Baitis et al. 1995), seasickness and its after-effects remain potential threats to crewmembers at sea. Understanding the incidence, severity and the effects of these motion-induced phenomena on performance, can improve safety, effective scheduling, task assignment, and productivity. A recent study by Haward et al. (2000) on a similar type of vessel in the North Sea suggested that although the incidence of vomiting was low, the magnitude of vessel acceleration experienced was highly correlated with the symptom complex of seasickness. In addition, there were reports of performance decrement in gross motor tasks such as moving, lifting and carrying loads.

This study attempts to (1) define the incidence and severity of the symptom complex of seasickness, motion-induced fatigue and task performance problems encountered on the Terra Nova FPSO vessel; and (2) examine correlations (if any) between FPSO vessel motion, fatigue, seasickness, and task performance. The information obtained will facilitate the development of operational guidelines for the Operational Installation Manager to ameliorate aversive motion effects and to set future priorities with respect to safety, human comfort, performance and engineering activities in the environment described above. The results of this study will add to the knowledge base leading to a better understanding of seasickness, motion-induced fatigue and motion-induced interruptions in this new type of offshore drilling vessel. This report presents the preliminary assessment based on data collected from December 2001 to June 2002.

Methods

Subjects

The subjects are employees of the Terra Nova project including trades people, technical personnel, project engineers and project managers. Approval of this survey study was obtained from the DRDC-Toronto (formerly DCIEM) Human Ethics Committee. All participants met the medical requirements as offshore employees and went through the medical screening provided by Atlantic Offshore Medical Services. Subjects were encouraged to participate, but were free to withdraw at any time without specifying a reason. All participants in this study were volunteers. The Terra Nova project enforces strict prohibition of alcohol consumption immediately prior to departure and during time spent on the FPSO vessel. Therefore, the survey was conducted away from the influence of alcohol. The data was collected by the duty Offshore Health Advisors (OHA) on a daily basis and was brought ashore at the end of a three-week shift offshore

Experimental design

Each employee on board of the FPSO vessel was assigned a numerical code by the medical team (from Atlantic Offshore Medical Services) responsible for distributing and collecting the questionnaires and forwarding to the principal investigator. The questionnaire data remained anonymous and is treated as confidential. Prior to the commencement of the study, crewmembers were given a briefing on the objectives of the study by the designated representatives from Atlantic Offshore Medical Services.

Procedure

Assessment of motion effects

Two questionnaire-based surveys of the crewmembers including a motion sickness history questionnaire (a survey on past motion sickness susceptibility, Golding, 1998, Appendix 1) and a motion effects assessment questionnaire were administered at various times as described below. The motion effects assessment questionnaire was based on the NATO Performance Assessment Questionnaire (Colwell 2000) but modified for use in this study. A copy of the Motion Effects Assessment is attached in Appendix 2.

The motion sickness history questionnaire was administered by the OHA to each of the crewmembers before reporting for duty on board the FPSO vessel. The motion effects assessment questionnaire was given to the participants as single page questions. During a 3-week shifts offshore, participants were encouraged to answer the questionnaire one half hour before shift end every day of the first week at sea and on designated days of the second and third week as determined by the marine weather forecast. Ideally, in the second and third week, data was collected during mild sea

(sea state 3-4) and rough sea state (sea state 5 and above). In addition, on any other day during rough weather when participants wished to use anti-motion sickness drugs, they were encouraged to answer an additional questionnaire prior to receiving medication from the OHA. In the event that a transfer vessel was required to transport the crew to the FPSO vessel, all passengers were encouraged to answer a separate Motion Effects Assessment (Appendix 1) upon arrival on the FPSO. All questionnaire surveys were collected by the Operation Health Advisor (OHA) on board the FPSO vessel in sealed envelopes and sent to the principal investigator.

Acquisition of ship motion data

It was our intention that FPSO motion data in six axes (roll, pitch, yaw angular accelerations and vertical, longitudinal, lateral acceleration) was to be measured at two designated locations on board, (the forward switch room and aft switch room on the same deck) by two independent accelerometers and data acquisition systems. The major indicator of vessel motion was intended to be the root-mean-square average acceleration magnitude, at the designated position, calculated over each measurement period. The maximum duration of recording was intended to be 24 hours including a 12-hour day shift and 12-hour night shift. However, due to administrative and subsequent technical delay in the delivery and testing of the necessary motion sensors (accelerometers) and other hardware required for data acquisition, real time ship motion sensing was not available on time for the study. Therefore, we considered this report to be the results of a preliminary study on motion effects based on ship motion data provided in the following manner. The radio operator from the FPSO Offshore Installation Office provided information on visibility, heading, wind direction, wind speed, pitch, roll, heave, mean heave rate, heave period, wave direction, maximum combined seas, swell height, wind wave, significant sea and temperature. The ship's roll and pitch angle and magnitude and velocity of heave were measured by the Seatex Motion Reference Unit motion sensor located forward on the ship at the helideck level, normally used for helideck motion analysis. This information was sampled at 0530, 1130 and 1730 hrs of each day. Some of the technical motion parameters were defined as follows:

1. Pitch: Rotation about the interaural axis (an axis that runs from ear to ear)

2. Roll: Rotation about the nasooccipital axis (an axis that runs from front to back)

3. Heave: Translation along the spinal axis (spine)

4. Mean Heave Rate: Average taken over a 5 minute period measured in metres/second

5. Heave Period: Time it takes vessel to travel one cycle (up-down)

6. Maximum Combined Seas: Maximum sea wave generated over a 20-minute period consists of the swell height and wind wave.

7. Swell Height: Height in metres of the primary non-wind driven wave component during a 20 minutes sample.

8. Wind Wave: Waves produced when the wind comes in contact with the sea.

9. Significant Sea: Average height of the highest one-third of all the waves during a 20 minutes period.

Data analysis

Motion Sickness Susceptibility Questionnaire (MSSQ)

A modified motion sickness susceptibility questionnaire (MSSQ, Golding 1998) was used to elucidate motion sickness history from the participating subjects. The MSSQ uses simplified scoring to produce adult reference norms. The test-retest reliability may be assumed to be better than 0.8. The predictive validity of the MSSQ for motion sickness tolerance using laboratory motion devices averaged at r = 0.45. It suggests that this questionnaire can be used with confidence.

Scoring subject input

The data was analyzed on fixed 12-hour intervals, based on the FPSO crew's 12-hour shift schedule. The majority of the motion effects assessments were scored on a four-point scale from zero through three; corresponding to none through severe. The seasickness rating was scored on an eleven-point scale (0 through 10). The higher score corresponds to a greater severity of the specific category of symptoms, and a score of zero indicates the described condition as "not present". Most of the other parameters were scored on a two-point score (i.e. yes/no), where no is scored as zero, and yes is scored as one. There are a total of 44 parameters under 6 major categories: sleep problems, symptoms of sickness, severity of sickness, performance problems, task completion problems, and other problems experienced during the scheduled period.

Null responses

For the analyses reported in this study, all null responses were counted as a response of zero (i.e. no problem). The effects of scoring null responses as zero, versus their omission from the analysis were small for those parameters considered.

Weighted Severity score

A weighted severity (WS) score, expressed as a percent of maximum possible score, was used to quantity the severity of each of the problems listed under each category in the Motion Effects Assessment questionnaire (Colwell 2000).

The general form of weighted severity is:

$$WS = \frac{100\sum_{i=1}^{\mathrm{Im}\,ax} iN_i}{\mathrm{Im}\,ax\sum_{i=0}^{\mathrm{Im}\,ax} Ni}$$

where i denotes the response score, I_{max} is the maximum score in the response scale, and Ni is the number of subjects reporting score i.

For the four-point scale, *Imax* =3, and WS is calculated as follows:

$$WS = \frac{100(N_1 + 2N_2 + 3N_3)}{3N_{subjects}}, \; N_{subjects} = N_0 + N_1 + N_2 + N_3$$

Where N_0 is the number of subjects scoring "0" (no problem), N_1 is the number of subjects scoring "1" (mild problem), N_2 is the number of subjects scoring "2" and N_3 is the number of subjects scoring "3".

For parameters with the two-point "yes/no" scale, WS reduces to percent of subjects responding yes (i.e. 100 $N_1/N_{subjects}$) and for the eleven-point seasickness scale; the WS summation expands to the maximum score of 10.

Correlation analysis

In this study, variables from the questionnaire under consideration were measured on an ordinal (rank order) scale. As a conservative measure, Spearman's rho correlation analysis was employed. The Spearman correlation between two variables is calculated by first reducing the sample values of each variable, separately, to ranks. A correlation coefficient indicates the degree of linear relationship between two variables. A positive correlation suggests that, as the observed values on one variable increase or decrease, the observed values on the other variable increase or decrease proportionately. A correlation of 0 suggests that there is not a linear relationship between the two variables. In this study, the correlation analysis discusses only those cases with sufficiently high statistical significance to reject the associated null hypotheses. Since $N_{subjects}$ is relatively high (a total of 43 participants), a critical ratio z test was employed. A p level of 0.01, which defines a 1% chance that the correlation is random, is accepted as the level denoting statistical significance. Accordingly, p-levels lower than 0.01 are significant (less likely to be random) and p-levels values higher than 0.01 are not statistically significant (more likely to be random).

Reliability of responses

Relative reliability of responses were based on the participation rate from the crew, i.e., percent of crew returning the Motion Effects Assessment and that it was completed according to the instructions given.

Results

Participation rate

Between December 2001 and June 2002, 52 consent forms and 49 motion sickness susceptibility questionnaires were returned. A cumulative total of 911 motion effects assessment questionnaires were returned from 43 subjects (participation rate was 82.7%). The reasons for non-participation were not investigated. The participants were 41 male and 2 female, ranging in age from 27 to 53 years (mean age = 39.3 years ± 5.9). Twenty-two subjects responded to the survey during multiple (more than 2) shifts offshore while twenty-one subjects responded to the survey only once. The distribution of participants relative to the total number of tours participated is tabulated as follows in Table 1:

Table 1. Participation rate

NUMBER OF SUBJECTS	TOTAL # OF TOURS PARTICIPATED
7	5
5	4
5	3
5	2
21	1

General responses

The average number of questionnaires filled out by each subject is about 9 with a range of 7 to 18. There were only two subjects provided responses for 3 and 5 tours respectively who reported no symptoms and encountered no problems. One other subject reported slight headache and another reported poor quality of sleep and slight physical fatigue for the entire shifts offshore as their sole complaint.

The majority of the problems relating to sleep and symptoms of motion sickness were at the slight to moderate level. Twelve subjects reported severe symptoms ranging from poor quality of sleep, physical fatigue, mental fatigue, headaches and severe nausea. Most of the problems relating to task performance were reported to be at the slight to moderate level with one exception of severe imbalance.

The distribution of the returned surveys across the seven-month period is as follows in Table 2:

Table 2. Distribution of returned surveys

MONTH	TOTAL # OF SURVEYS	TOTAL # OF SUBJECTS
December 2001	99	16 (12 continued into January)
January 2002	277	39 (10 continued into February)
February 2002	139	24 (5 continued into March)
March 2002	102	16 (7 continued into April)
April 2002	98	16 (4 continued into May)
May 2002	107	17 (1 continued into June)
June 2002	89	13

Motion Sickness History Questionnaire

Cumulative distribution (percentile) of Motion Sickness Susceptibility Questionnaire Scores based on Golding (1998) ranged from 0% to 96% with a mean of 32.4% ± 32.7.

Ship motion

For each month the thrice-daily report of ship motion data, including pitch, roll, heave, mean heave rate, heave period, maximum combined seas and significant sea, are illustrated in Figures 1-7 in the annexe.

Correlations between motion effects and ship motion

The relationships between ship motion and the motion effect assessment parameters for each month are tabulated in Tables 7-13 in the annexe. Only correlation coefficient with $p < 0.01$ are presented.

Sleep problems

Subjects reported insufficient duration of sleep, a parameter correlated with maximum combined sea, wind wave and significant sea, in some cases (e.g. June) the correlation is as high as 0.56. Sleep problems appear to be attributed to various ship motion parameters with a correlation of 0.47 with mean heave rate and were also attributed to seasickness with a correlation of 0.29 in January 2002. The percentage of participants who experienced this problem are listed in the following Table 3:

Table 3. Percentage of participants experiencing sleep problems

SLEEP PROBLEMS	JANUARY	JUNE
Poor quality of sleep	79.5%	38.5%
Insufficient sleep	82.1%	46.2%

Motion-induced sickness

In general, heave motion provides the most frequent correlation with the motion sickness parameters. However, the pitch angle and to a lesser extent, roll angle correlate significantly with motion sickness symptoms which ranged from dizziness to depression. Again, January is the only month that the degree (severity) of sickness is correlated with pitch, roll and heave motion. The percentage of participants who experienced any symptoms of motion sickness at least once is 84.6%.

Task performance

Problems with task performance include cognitive task performance such as problems making decisions, loss of concentration, and memory problems, were observed in December, January, February and May. The correlation coefficient ranged from 0.29 to as high as 0.50 with a significance of $p < 0.0001$. Problems with simple tasks such as adding and spelling were reported only in February. Among the physical task performance parameters, problems with body motion/balance and problems with carrying/moving objects shows significant correlation in December through March and in May. The most notable difficulties encountered were in January and February with a correlation coefficient of 0.77 between problems in carrying objects and ship motion (See Table 8 and 9). It has been established by previous investigators in the laboratory (Baitis et al. 1995, Wertheim 1996, Wertheim & Kistemaker 1997) that motion-induced interruptions occur when standing on a moving surface such as on the deck of moving vessels. The effort in stabilizing oneself, such as grasping for handrails, under such circumstances, interrupts the task being undertaken and also has significant implications for safety in the workplace. The percentage of participants who experienced this problem are listed in the following Table 4:

Table 4. Correlations between task performance and month

TASK PERFORMANCE PROBLEMS	DECEMBER	JANUARY	FEBRUARY	MARCH	MAY
Decision making	43.8%	38.5%	29.2%		5.9%
Concentration	50%	69.2%	54.2%		35.3%
Memory	37.5%	46.2%	29.2%		11.8%
Simple tasks (adding/spelling)			16.7%		
Body motion/balance	50%	64.1%	50%	25%	29.4%
Carrying/moving heavy objects	31.3%	58.9%	29.2%	18.8%	11.8%

Task completion

A significant correlation between task completion problems and vessel motion was observed in 3 months. In December, the swell height is correlated ($r = 0.38$, $P = 0.0006$) to the parameter where the "task took much longer to complete". In January, there were reports of making more mistakes than usual, taking longer to complete tasks and in some cases, the task had to be abandoned. These problems encountered in task performance correlated with the ship motion with correlation coefficient ranging from 0.32 to 0.64. The last case appeared in April where the parameter of "not allowed to attempt tasks" is correlated with heave motion, maximum combined sea and significant sea. The percentage of participants who experienced this problem are listed in the following Table 5:

Table 5. Correlations between task completion and month

TASK COMPLETION PROBLEMS	DECEMBER	JANUARY	APRIL
Made more mistakes		23.1%	12.5%
Took longer to complete task	37.5%	46.2%	18.8%
Forced to abandon task		7.7%	
Not allowed to attempt task			6.25%

Other correlations of statistical significance

The following Table 6 shows correlation between mental and physical fatigue, concentration and environmental factors with a variety of parameters.

Table 6. Correlations between mental and physical fatigue, concentration and environmental factors

FATIGUE	CORRELATION COEFFICIENT
Mental fatigue & poor sleep quality	0.37, p < 0.0001
Mental fatigue & decision making problems	0.63, p < 0.001
Mental fatigue & memory deficit	0.54, p < 0.0001
Mental fatigue & simple task problems	0.56, p < 0.0001
Mental fatigue & eye-hand co-ordination deficit	0.32, p < 0.0001
Mental fatigue & tasks took longer	0.50, p < 0.0001
Mental fatigue & task abandoned	0.13, p = 0.0001
Physical fatigue & poor sleep quality	0.40, p < 0.0001
Physical fatigue & decision-making problems	0.53, p < 0.0001
Physical fatigue & memory deficit	0.47, p < 0.0001
Physical fatigue & simple task problems	0.50, p < 0.0001
Physical fatigue & eye-hand co-ordination deficit	0.29, p < 0.0001
Physical fatigue & tasks took longer	0.49, p < 0.0001
Physical fatigue & task abandoned	0.16, p = 0.0001
COGNITIVE PERFORMANCE	**CORRELATION COEFFICIENT**
Concentration deficit & stomach awareness	0.39, p < 0.0001
Concentration deficit & mental fatigue	0.73, p < 0.0001
Concentration deficit & physical fatigue	0.65, p < 0.0001
Concentration deficit & short sleep time	0.36, p < 0.0001
Concentration deficit & noise	0.54, p < 0.0001
Concentration deficit & sleepiness	0.49, p < 0.0001
Concentration deficit & task took longer	0.59, p < 0.0001
Concentration deficit & task abandoned	0.20, p < 0.0001
OTHERS	**CORRELATION COEFFICIENT**
Stomach awareness & balance problem	0.47, p < 0.0001
Stomach awareness & task took longer	0.39, p < 0.0001
Noise & short sleep time	0.28, p < 0.0001
Vibration & Short sleep time	0.24, p < 0.0001
Temperature & short sleep time	0.23, p < 0.0001
Cold/flu & nausea	0.41. p < 0.0001

Discussion

It should be emphasized that, due to the reasons stated under "Ship Motion Data Acquisition", we were not able to obtain the main indicator of the severity of vessel motions based on the root-mean-square average acceleration magnitude as normally employed in such studies. An accurate translational acceleration measurement at two or three locations on the same deck is required to compute the motions of the vessel in the three rotational and three translational axes so that the acceleration in all six axes (x, y, z, roll, pitch and yaw) at any point on the vessel can then be known. The ship motion data provided for the current analysis is based on data gathered from the helideck (at the bow of the FPSO vessel) motion analysis. Therefore, the motion data employed might be at variance or may not accurately reflect ship motion at other locations on board the FPSO vessel. The fidelity of the motion data should be improved with actual measurements. Nevertheless the preliminary result has brought to light a number of potential problems related to operating the FPSO in an efficient manner.

A potential concern for the evaluation of multiple parameters involving a large group of subjects is that almost all parameters may correlate. It is typical that many parameter combinations may show correlation at least at the 0.05-level. This appears not to be the case with the data collected to date. Our analysis demonstrated that the correlation between the magnitudes of ship motion and some of the parameters of motion effects are significant often with a p value much less than 0.01. In many cases, it is highly significant with $p < 0.0001$.

The number of responses to the survey appears to reflect the weather conditions of the particular months. For example, the number of questionnaires returned in January was almost 3 times higher than in December 2001. Similarly, the number of significant correlations between the various symptoms of sickness, performance decrement and ship motion was also much higher in January and February than other months. This may be attributed to the inclement weather during these two winter months and is reflected by the increased magnitude of ship motion especially in heave motion, maximum combined sea and significant seas.

Although the incidence of vomiting and frank sickness were low, there was a correlation between the magnitudes of pitch, roll, heave, mean heave rate, maximum combined seas, swell height, wind wave and significant seas recorded on the FPSO vessel, and sleep problems, symptoms experienced, and task performance and completion. Many groups of motion effects have similar correlation behaviour. For example, the correlation between motion effects and heave ship motion were very similar to those with pitch angle, as both are measures of ship vertical motion. Other groups of parameters with similar correlation behaviour include symptoms and severity of sickness experienced. Our analysis demonstrated that there were correlations between the magnitudes of roll and pitch motion of the FPSO vessel and sleep problems, symptoms experienced, task performance, and task completion. Similarly, there were correlations between heave motion and sleep problems, symptoms experienced, and performance. It is of particular interest that performance problems were significantly ($p < 0.01$) affected by the increased magnitude of pitch, roll and heave. From a practical point of view, this information can be taken into consideration when assigning daily task.

It has been shown that individuals who are subjected to a motion stimulus that provokes nausea and vomiting tend, with repeated exposure, to become increasingly resistant to its nauseogenic effect. This habituating response is often observed in a variety of situations such as on board ships, during space flight, and in a number of laboratory stimuli. Although this survey was designed and conducted as a cross-sectional study, our data suggests that for the individuals that are susceptible to ship motion, their sickness symptoms and problems related to task performance problem do not improve with time. In other words, some subjects who experienced stomach awareness during the first week of a tour also reported the same symptom at an equivalent severity level during the second and third week and also in subsequent shifts offshore. It should be noted that the motion stimuli in the laboratory and indeed most commercial transport vehicles are relatively constant while the FPSO motion depends largely on weather conditions, which are less predictable. Furthermore, as indicated earlier under "Participation rate", the number of subjects who responded on multiple tours is relatively low. Participants begin their shifts offshore at various times of the month and of the year; therefore, scientific validation of the lack of habituation effect requires further investigation. A direct comparison with laboratory studies cannot be made.

In general, the relationship between motion sickness and the ability to perform is not clear and is inconsistent between results obtained from simulator studies as opposed to field studies. Field studies generally show degradation in performance as a result of motion sickness, however, the results are not conclusive in controlled laboratory studies. This is probably due to the fact that a number of other factors have not been taken into consideration - for example, the perception of helplessness, the inability to control the environment and motivation may play a significant role in performance degradation under operational environment.

Conclusion

The objectives of this study are to investigate if the method employed is appropriate and the interim findings are worthy of further investigation. The ability to self-administer questionnaire surveys is advantageous in that the information can be obtained relatively easily. However, the ability to self-assess performance needs to be validated against objective performance evaluations under a controlled environment. A relatively large database of fatigue, symptoms of motion sickness, and task performance problems on the FPSO vessel has been obtained. Our data suggests that crewmembers exposed to FPSO vessel motion were found to experience sleep disturbance and task performance difficulties that were dependent on ship motions. Physical and cognitive aspects of task performance appear to be equally affected by vessel motion. The correlation coefficients for decision/concentration and body motion/balance are similar. However, the magnitude of heave motion was more correlated with the disturbance of physical than cognitive performance. The correlation coefficient between "problems in carrying/moving things" and magnitude in heave reached as high as 0.7. Although there was low incidence of reported vomiting or frank sickness, a positive correlation between the signs and symptoms of motion sickness, sleep disturbance and vessel motion were frequently observed.

A large database is required to substantiate the observation that fatigue, sickness symptoms and task performance problems is associated with FPSO ship motions during severe weather. In this study we are unable to observe the effect of habituation to sea on any of the measured parameters due to the insufficient response from the number of affected subjects. A more regimental data collection from multiple shifts offshore is required to investigate the effect of habituation. Existing models on the effects of seasickness are based on short-term exposures to motion. They are not applicable for operations where crewmembers spend many days at sea. Although an empirical approach taking habituation into account was used in estimating motion sickness (Colwell 1994), the method is unproven for complex motion and not applicable to motions that change over time (as in the FPSO environment).

The effectiveness of any ship at sea is degraded by rough weather. Excessive ship motion may prevent crewmembers from performing their duties or, in the worst case, failing to complete them altogether. It is essential that appropriate operating procedures should be developed that will recognise the range of motions during which operations on board may be safely undertaken. In addition, clear guidance should be provided on operations as the motion conditions worsen. A key component in the development of such procedures and guidance will be further assessment (in the form of a longitudinal study) of motion effects on human performance, health, and safety.

Summary

1. Based on the number of returned questionnaires and the number of consents given, the participation rate of this study was 82.7%.

2. Many of the problems reported for sleep disturbance and motion sickness symptoms were slight to moderate.

3. High correlation was observed between sleep disturbance and ship motion.

4. January has the highest correlations between pitch, roll and heave motion with complaints of seasickness.

5. Task performance problems such as loss of concentration, decision making and memory disorders were noted in December, January, February and May when weather conditions were presumably poor. Percentage of subjects experienced task performance problems range from 5.8% to 69.2%.

6. Task completion was also noted as a problem by in December, January, and April. Percentage of subjects experienced task performance problems range from 6.3% to 46.2%.

7. There was no apparent habituation among subjects who participated in more than 2 shifts offshore.

8. It is apparent that the number of safety, health and performance issues increases with the deterioration of weather condition. With an increase in participants in future study; it is likely that the problem observed is only the "tip of the iceberg".

9. This data is only a preliminary assessment and can only be extenuated when it is possible to directly measure the motion of the FPSO using the planned data acquisition systems and a longitudinal study through the winter months.

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Annex 1

Symptoms

ID Number____________________

Mode of transportation to FPSO ☐ Helicopter ☐ Boat ☐

Date______________Shift start time________ Shift end time ______

Location____

Occupation____

Sleeping problems before this shift

0 = none; 3 = severe:	0	1	2	3
Quality of sleep was poor	☐	☐	☐	☐
Amount of time sleeping was short	☐	☐	☐	☐
Sleep problems caused by:				
ship motions (bouncing around)	☐	☐	☐	☐
seasickness	☐	☐	☐	☐
other:______________________	☐	☐	☐	☐

Symptoms experienced during this shift

0 = none; 3 = severe:	0	1	2	3
Dizziness	☐	☐	☐	☐
Mental fatigue	☐	☐	☐	☐
Physical fatigue	☐	☐	☐	☐
Sleepy	☐	☐	☐	☐
Headache	☐	☐	☐	☐
Apathy (just don't care)	☐	☐	☐	☐
Tension/anxiety	☐	☐	☐	☐
Vomiting or retching	☐	☐	☐	☐
Nausea (not vomiting, yet)	☐	☐	☐	☐
Stomach awareness	☐	☐	☐	☐
Cold sweating	☐	☐	☐	☐
Unmotivated (don't feel like doing anything)	☐	☐	☐	☐
Depressed	☐	☐	☐	☐
Other: ______________________	☐	☐	☐	☐

How sick are you? 0=feel fine; 10 = feel awful

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Are you taking seasickness medicine? Yes ☐ No ☐

Did you vomit before/during this shift? Yes ☐ No ☐

If yes, at about what time?___________

How did you feel after? Better ☐ Same ☐ Worse ☐

Performance

Task *performance* problems during this shift

0 = none; 3 = severe:	0	1	2	3	n/a
Making decisions	☐	☐	☐	☐	☐
Concentration/attentions	☐	☐	☐	☐	☐
Memory	☐	☐	☐	☐	☐
Simple tasks (adding, spelling)	☐	☐	☐	☐	☐
Body motion (balance)	☐	☐	☐	☐	☐
Carrying or moving things	☐	☐	☐	☐	☐
Eye hand coordination	☐	☐	☐	☐	☐
Vision	☐	☐	☐	☐	☐
Other:____________________	☐	☐	☐	☐	☐

Task *completion* problems during this shift

Made more mistakes than usual	Yes ☐	No ☐
Tasks took longer than usual	Yes ☐	No ☐
Tasks not completed in time available	Yes ☐	No ☐
Had to abandon task	Yes ☐	No ☐
Not allowed to attempt tasks	Yes ☐	No ☐
Other:____________________	Yes ☐	No ☐

Other problems during this shift

0 = none; 3 = severe:	0	1	2	3
Cold, flu, or other illness	☐	☐	☐	☐
Air quality (bad smells)	☐	☐	☐	☐
Noise	☐	☐	☐	☐
Vibration	☐	☐	☐	☐
Lighting (bright ☐, dark ☐)	☐	☐	☐	☐
Temperature (hot ☐, cold ☐)	☐	☐	☐	☐
Other:____________________	☐	☐	☐	☐

Comments____

____

____

____

Seasickness drugs taken: ______________________________

Annex 2

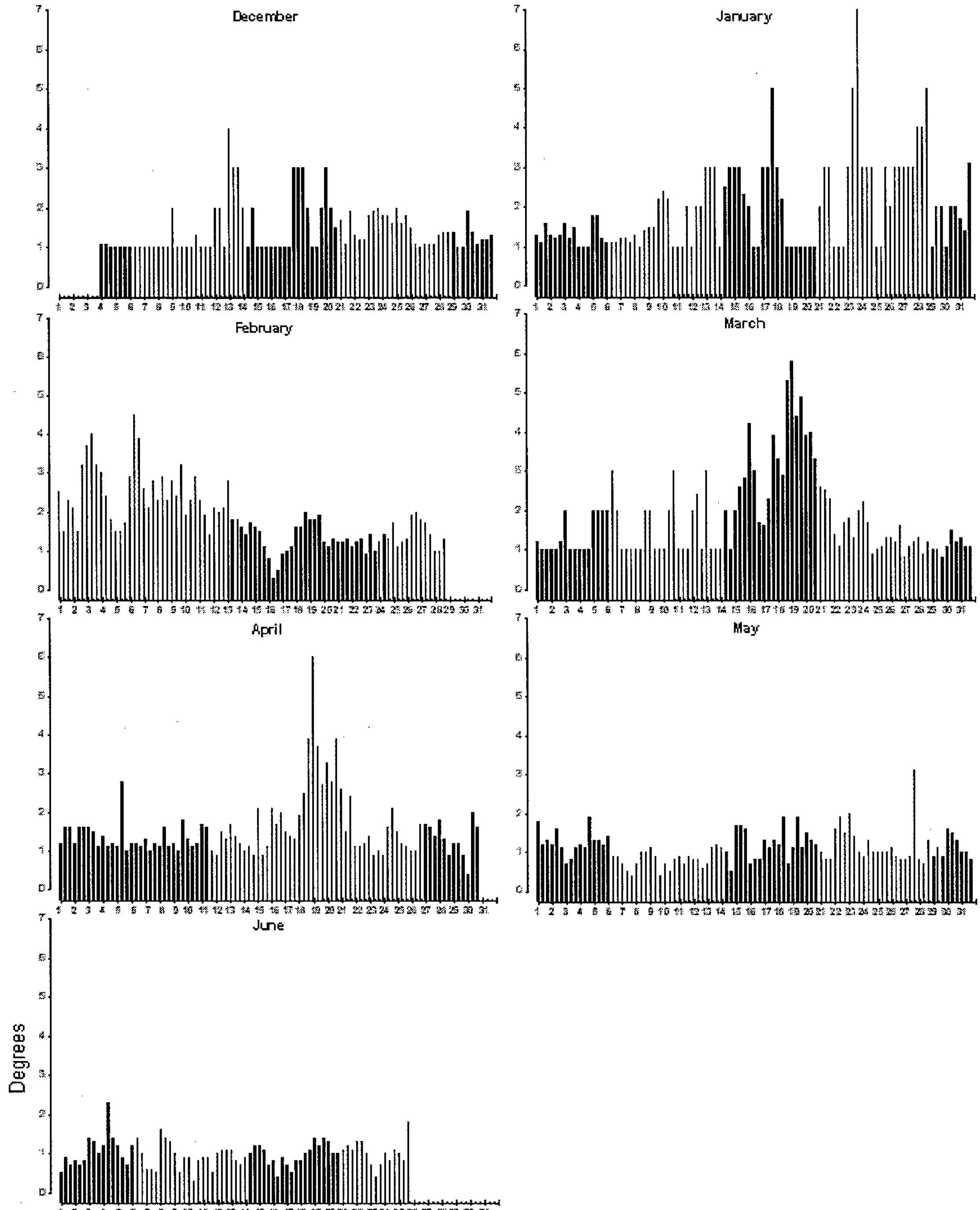

Figure 1. Monthly vessel data for the pitch parameter (3 data pts/day)

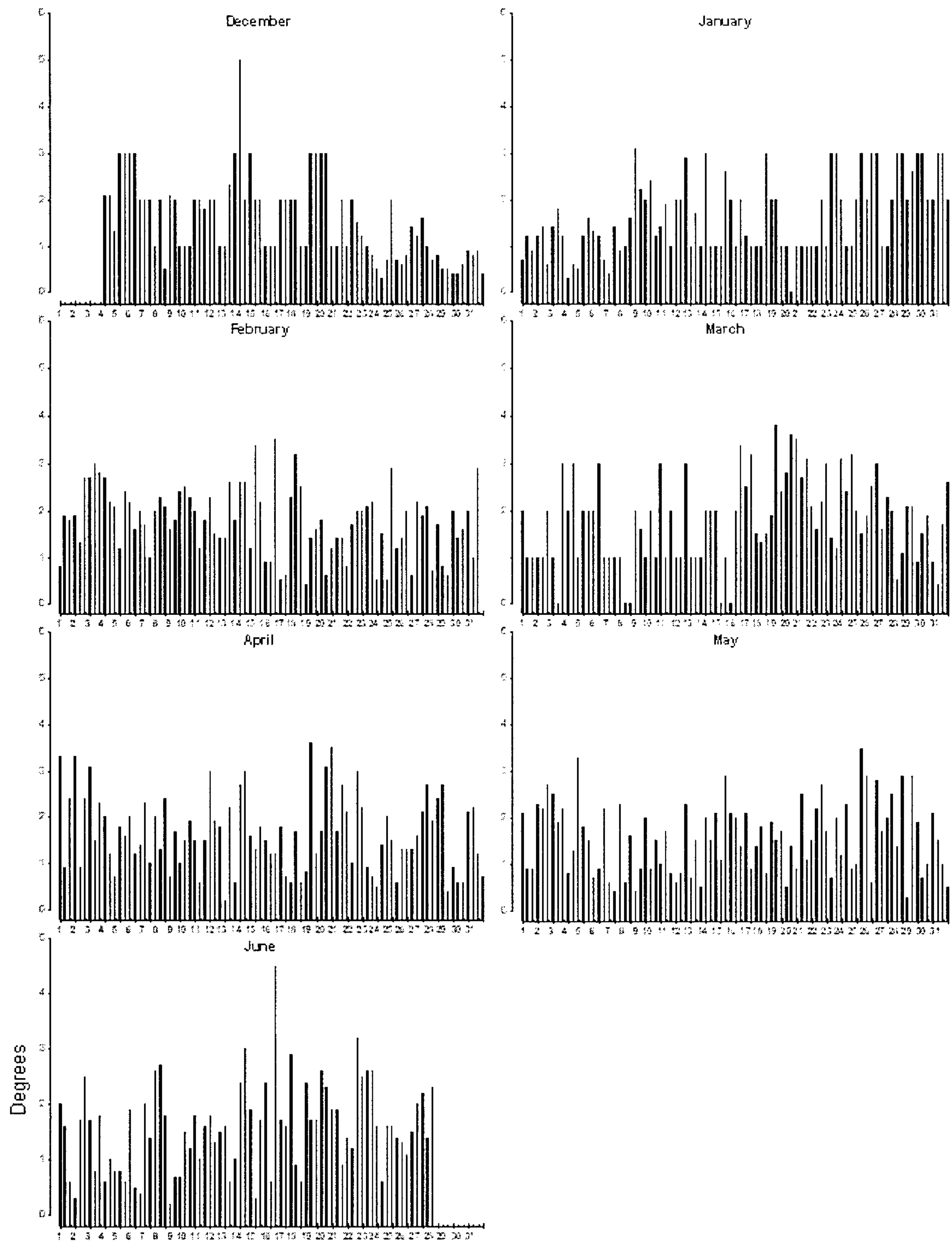

Figure 2. Monthly vessel data for the roll parameter (3 data pts/day)

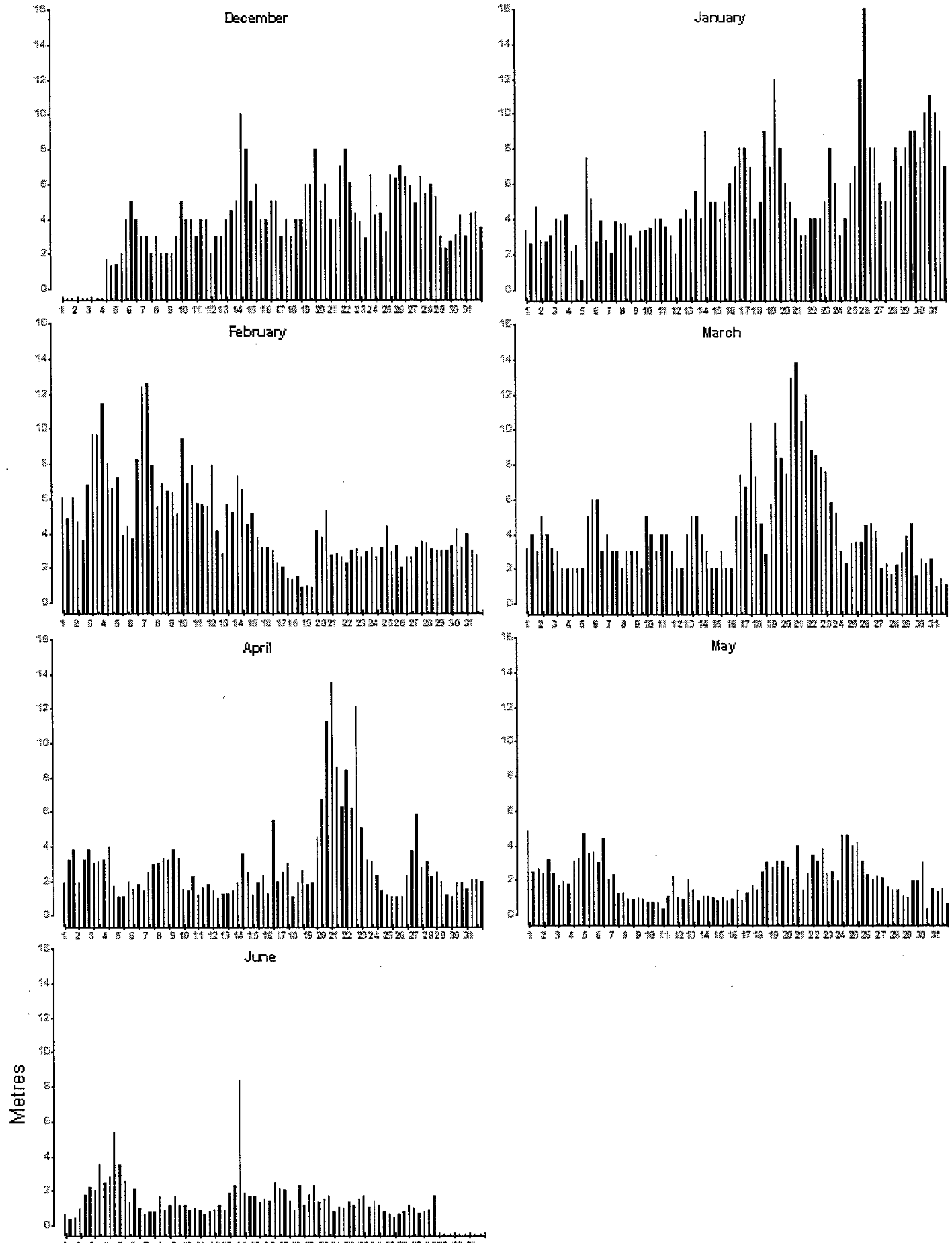

Figure 3. Monthly vessel data for the heave parameter (3 data pts/day)

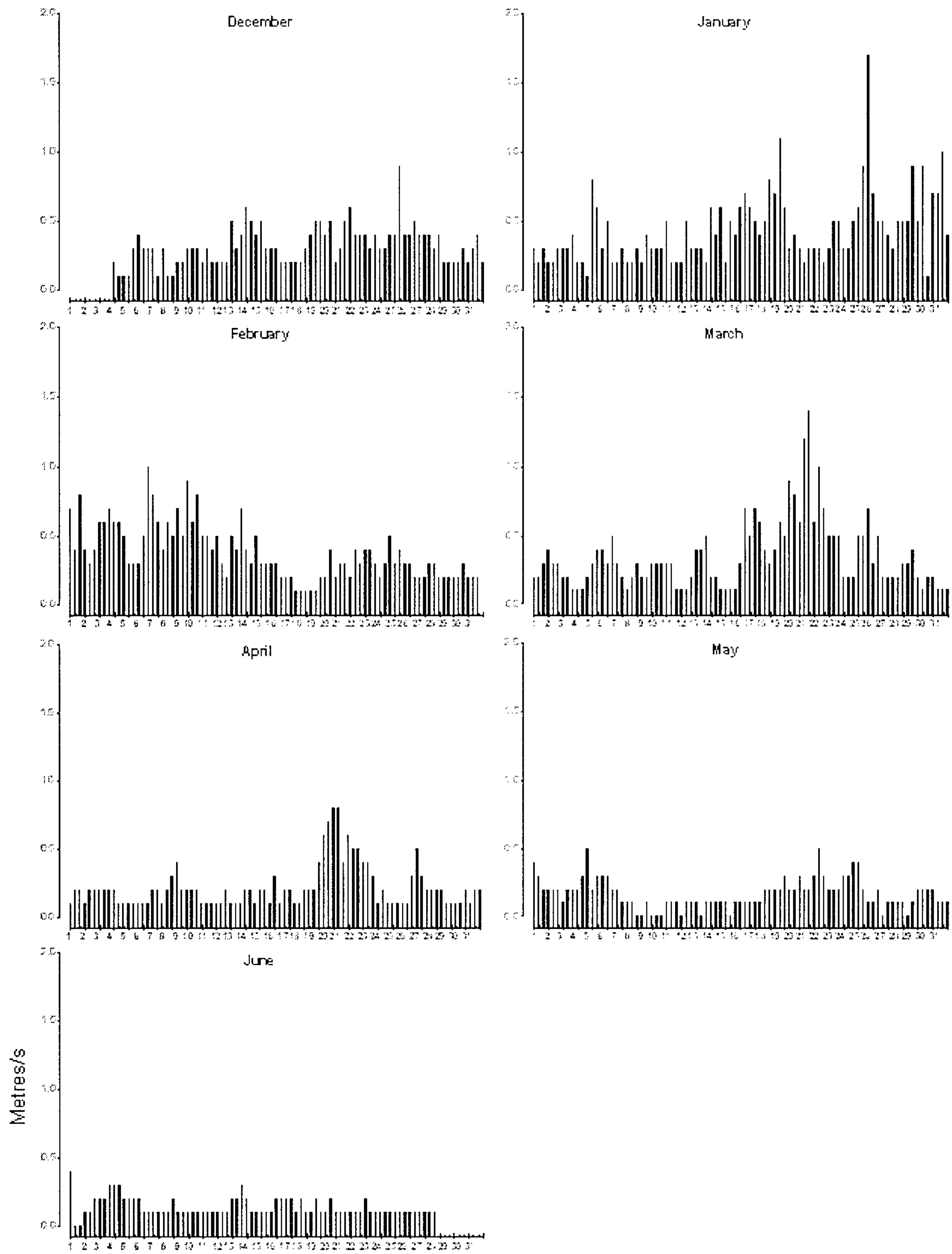

Figure 4. Monthly vessel data for the mean heave rate parameter (3 data pts/day)

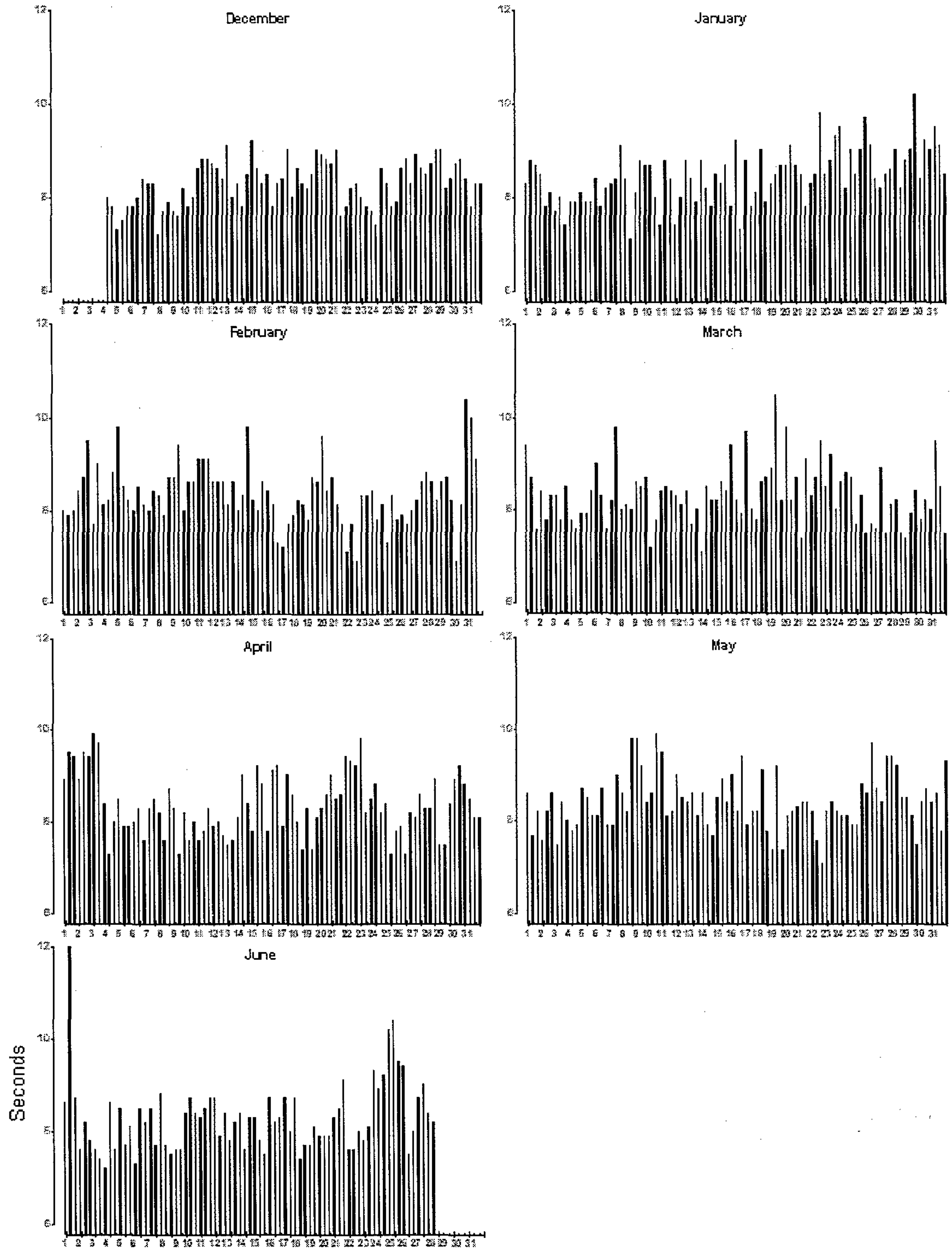

Figure 5. Monthly vessel data for the heave period parameter (3 data pts/day)

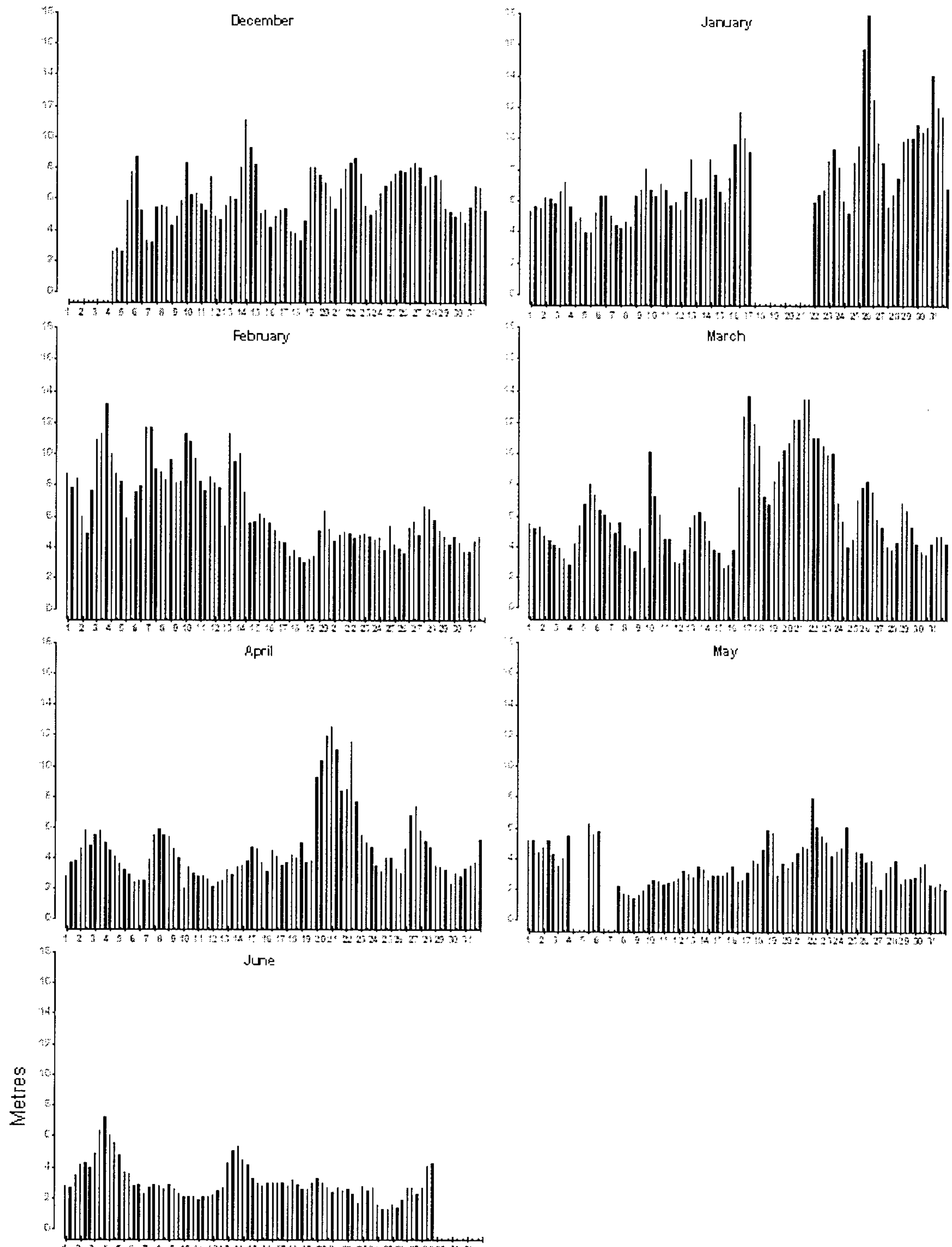

Figure 6. Monthly vessel data for the maximum combined seas parameter (3 data pts/day)

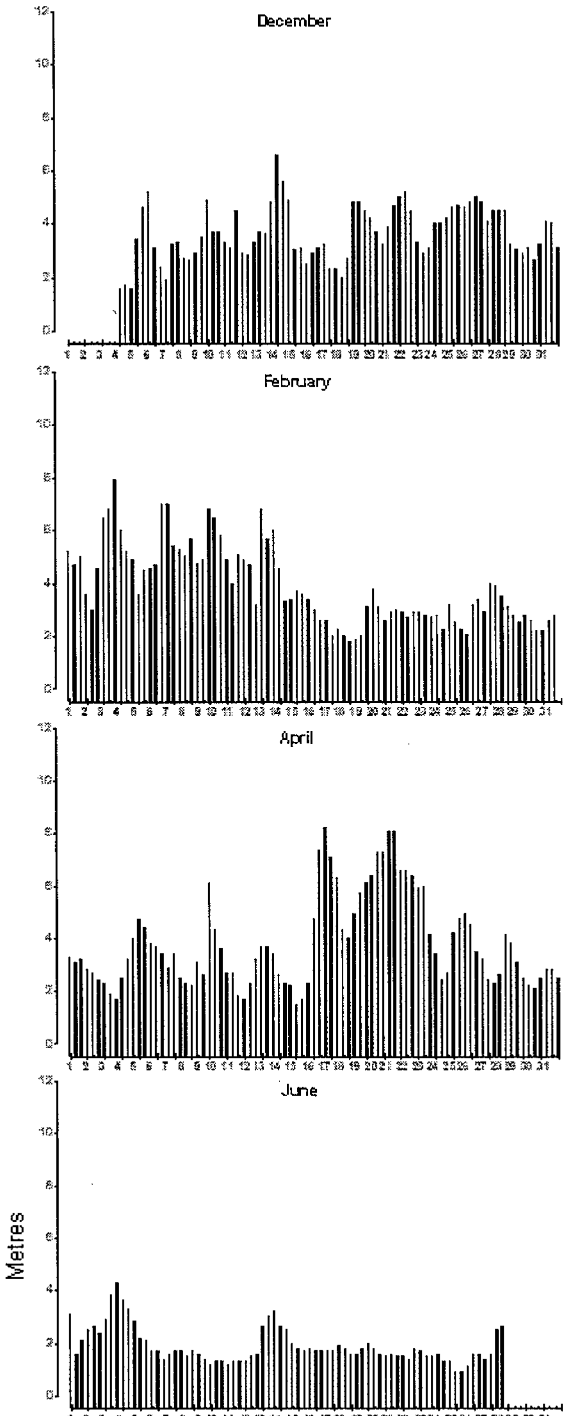

Figure 7. Monthly vessel data for the significant seas parameter (3 data pts/day)

Annex 3

Table 7. December symptom and motion parameter correlations

SYMPTOM	VESSEL MOTION PARAMETER		
	Pitch	***Roll***	***Swell height***
Mental fatigue		0.30 (p=0.0086)	0.42 (p=0.0001)
Physical fatigue			0.41 (p=0.0002)
Sleepy			0.40 (p<0.0003)
Tension/anxiety	0.29 (p=0.0010)		
Stomach awareness		0.40 (p=0.0025)	
Problems making decisions			0.33 (p=0.0027)
Concentration problems		0.38 (p=0.0005)	0.29 (p=0.0092)
Problems with body motion/balance		0.44 (p<0.0001)	0.32 (p=0.0038)
Problems carrying/moving things			0.31 (p=0.0050)
Tasks took longer than usual			0.38 (p=0.0006)

Table 8. January symptom and motion parameter correlations

SYMPTOM	VESSEL MOTION PARAMETER							
	Pitch	***Roll***	***Heave***	***Mean heave rate***	***Max combined seas***	***Swell height***	***Wind wave***	***Significant sea***
Amount of sleep time was short					0.30 (p=0.0073)			0.30 (p=0.0071)
Sleep problems:ship motion	0.27 (p=0.0080)		0.37 (p<0.0001)	0.47 (p<0.0001)	0.40 (p=0.0030)			0.41 (p=0.0002)
Sleep problems: seasickness				0.28 (p=0.0070)				
Dizziness	0.30 (p=0.0032)		0.36 (p=0.0003)	0.34 (p=0.0009)				
Mental fatigue	0.36 (p=0.0003)	0.30 (p=0.0038)	0.30 (p=0.0040)	0.33 (p=0.0010)	0.45 (p<0.0001)			0.45 (p<0.0001)
Physical fatigue	0.40 (p<0.0001)	0.32 (p=0.0020)	0.33 (p=0.0010)	0.37 (p=0.0003)	0.55 (<0.0001)		0.42 (p<0.0001)	0.55 (p<0.0001)
Sleepy		0.36 (p=0.0004)	0.39 (p=0.0001)	0.43 (p<0.0001)	0.56 (p<0.0001)		0.37 (p=0.0009)	0.56 (p<0.0001)
Headache	0.50 (p<0.0001)		0.44 (p<0.0001)	0.39 (p=0.0001)	0.59 (p<0.0001)		0.33 (p=0.0036)	0.60 (p<0.0001)
Apathy		0.30 (p=0.0035)						
Vomiting or retching				0.30 (p=0.0033)				
Stomach awareness			0.35 (p=0.0005)	0.28 (p=0.0063)				
Unmotivated		0.31 (p=0.0025)	0.27 (p=0.0100)		0.41 (p=0.0002)	0.32 (p=0.0047		0.40 (p<0.0001)
Other symptoms	0.29 (p=0.0040)		0.31 (p=0.0030)	0.36 (p=0.0004)				
Degree of sickness	0.35 (p=0.0007)	0.36 (p=0.0004)	0.41 (p<0.0001)	0.34 (p<0.0001)				

Table 8 continued. January symptom and motion parameter correlations

SYMPTOM	VESSEL MOTION PARAMETER							
	Pitch	***Roll***	***Heave***	***Mean heave rate***	***Max combined seas***	***Swell height***	***Wind wave***	***Significant sea***
Taking seasickness medicine				0.29 (p=0.0052)	0.30 (p=0.0072)	0.41 (p=0.0002)		0.34 (p=0.0024)
Problems making decisions				0.29 (p=0.0033)	0.35 (p=0.0001)			0.37 (p=0.0010)
Concentration problems	0.41 (p<0.0001)	0.34 (p<0.0001	0.38 (p<0.0002)	0.40 (p<0.0001)	0.48 (p<0.0001)			0.52 (p<0.0001)
Memory problems	0.27 (p=0.0100)				0.51 (p<0.0001)			0.49 (p<0.0001)
Problems with body motion/balance	0.40 (p<0.0001)	0.33 (p=0.0017	0.48 (p<0.0001)	0.49 (p<0.0001)	0.44 (p<0.0001)			0.44 (p<0.0001)
Problems carrying/moving things		0.27 (P=0.0093	0.29 (P=0.0046)	0.30 (p=0.0034)	0.38 (p=0.0007)			0.38 (p<0.0001)
More mistakes than usual	0.39 (p<0.0001)			0.34 (p=0.0008)	0.42 (p=0.0001)			0.43 (p=0.0001)
Tasks took longer than usual	0.44 (p<0.0001)	0.42 (p<0.0001	0.45 (p<0.0001)	0.50 (p<0.0001)	0.65 (p<0.0001)	0.30 (p=0077)	0.42 (p=0.0001)	0.64 (p<0.0001)
Had to abandon task	0.33 (p=0.0012)		0.32 (p<0.0016)	0.32 (p=0.0016)				

Table 9. February symptom and motion parameter correlations

SYMPTOM	VESSEL MOTION PARAMETER						
	Pitch	***Heave***	***Mean heave rate***	***Max combined seas***	***Swell height***	***Wind wave***	***Significant sea***
Sleep problems: ship motion	0.42 ($p<0.0001$)	0.33 ($p<0.0020$)	0.42 ($p<0.0001$)	0.44 ($p<0.0001$)	0.39 ($p<0.0031$)		0.43 ($p<0.0001$)
Dizziness		0.29 ($p<0.0088$)					
Headache	0.29 ($p<0.0069$)	0.33 ($p<0.0022$)	0.48 ($p<0.0001$)	0.31 ($p<0.0039$)		0.31 ($p<0.0036$)	0.30 ($p<0.0050$)
Vomiting or retching		0.29 ($p<0.0078$)	0.36 ($p<0.0007$)	0.32 ($p<0.0032$)		0.35 ($p<0.0010$)	0.32 ($p<0.0031$)
Nausea (not vomiting)						0.32 ($p<0.0033$)	
Cold sweating			0.29 ($p<0.0088$)			0.35 ($P=0.0012$)	
Depressed			0.29 ($p<0.0086$)				
Problems making decisions	0.40 ($p<0.0001$)		0.32 ($p<0.0037$)	0.36 ($p<0.0009$)			0.36 ($p<0.0011$)
Memory problems	0.48 ($p<0.0003$)	0.42 ($p<0.0001$)	0.50 ($p<0.0001$)	0.49 ($p<0.0001$)	0.42 ($p<0.0017$)	0.30 ($p<0.0012$)	0.49 ($p<0.0001$)
Problems with simple tasks	0.48 ($p<0.0001$)	0.40 ($p<0.0003$)	0.52 ($p<0.0001$)	0.44 ($p<0.0001$)		0.46 ($p<0.0051$)	0.49 ($p<0.0001$)
Problems with body motion/balance	0.38 ($p<0.0002$)	0.49 ($p<0.0001$)	0.42 ($p<0.0001$)	0.48 ($p<0.0001$)		0.42 ($p<0.0001$)	0.50 ($p<0.0001$)
Problems carrying/moving things	0.64 ($p<0.0001$)	0.70 ($p<0.0001$)	0.71 ($p<0.0001$)	0.74 ($p<0.0001$)	0.45 ($p<0.0007$)	0.70 ($p<0.0001$)	0.77 ($p<0.0001$)
Eye hand coordination problems						0.31 ($p<0.0043$)	
Visions problems	0.43 ($p<0.0001$)	0.37 ($p<0.0006$)	0.46 ($p<0.0001$)	0.44 ($p<0.0001$)		0.47 ($p<0.0001$)	0.44 ($p<0.0001$)

Table 10. March symptom and motion parameter correlations

SYMPTOM	VESSEL MOTION PARAMETER						
	Pitch	***Roll***	***Heave***	***Mean heave rate***	***Max. combined seas***	***Wind wave***	***Significant sea***
Sleep problems: ship motion	0.30 (p=0.0040)		0.28 (p=0.0072)	0.37 (p=0.0002)		0.34 (p=0.0011)	
Sleepy	0.49 (p<0.0001)		0.38 (p=0.0001)	0.44 (p<0.0001)		0.32 (p=0.002)	
Headache	0.37 (p<0.0001)	0.31 (p=0.0022)		0.29 (p=0.0047)			
Problems with body motion/balance	0.48 (p=0.0001)		0.47 (p<0.0001)	0.44 (p<0.0001)	0.41 (p<0.0001)	0.38 (p=0.0002)	0.38 (p=0.0002)
Problems carrying/moving things	0.41 (p=0.0001)		0.41 (p=0.0001)	0.37 (p=0.0003)	0.36 (p=0.0004)	0.32 (p=0.0019)	0.35 (p=0.0008)
Eye hand coordination problems					0.32 (p<0.0021)	0.30 (p=0.0044)	0.31 (p=0.0029)

Table 11. April symptom and motion parameter correlations

SYMPTOM	**VESSEL MOTION PARAMETER**				
	Heave	***Mean heave rate***	***Max. combined seas***	***Wind wave***	***Significant sea***
Not allowed to attempt task	0.28 (p=0.0093)	0.31 (p=0.0046)	0.30 (p=0.0055)	0.30 (p=0.0051)	0.30 (p=0.0051)

Table 12. May symptom and motion parameter correlations

SYMPTOM	VESSEL MOTION PARAMETER					
	Pitch	***Heave***	***Mean heave rate***	***Max. combined seas***	***Swell height***	***Significant sea***
Sleep problems: ship motion		0.30 (p=0.0070)		0.35 (p=0.0029)		0.40 (p=0.0007)
Mental fatigue		0.34 (P=0.0023)	0.36 (p=0.0011)	0.37 (p=0.0012)	0.40 (p<0.0027)	0.36 (p=0.0018)
Physical fatigue		0.31 (P=0.0069)	0.35 (p=0.0018)	0.31 (p=0.0083)		0.31 (p=0.0083)
Headache	0.33 (p=0.0035)	0.54 (p<0.0001)	0.54 (p<0.0001)	0.47 (p<0.0001)	0.47 (p<0.0003)	0.47 (p<0.0001)
Apathy	0.31 (p=0.0063)	0.32 (p=0.0042)	0.31 (p=0.0056)			
Nausea (not vomiting)		0.33 (p<0.0027)		0.33 (p=0.0056)		0.34 (p=0.0041)
Stomach awareness		0.39 (p=0.0005)	0.30 (p=0.0076)			0.36 (p=0.0017)
Cold sweating	0.31 (p=0.0055)	0.36 (p=0.0018)				
unmotivated		0.30 (p=0.0092)	0.31 (p=0.0063)			
Degree of sickness		0.45 (p<0.0001)	0.38 (p=0.0005)	0.50 (p<0.0001)	0.49 (p<0.0001)	0.53 (p<0.0001)
Problems making decisions		0.34 (p=0.0031)	0.30 (p=0.0082)			
Problems with simple tasks		0.34 (p=0.0026)	0.30 (p=0.0074)			
Problems with body/motion balance	0.38 (p=0.0007)	0.41 (p=0.0003)	0.37 (p<0.0008)			0.31 (p=0.0090)
Problems carrying/moving things	0.40 (p=0.0006)	0.52 (p<0.0001)	0.44 (p<0.0001)	0.32 (p=0.0058)		0.36 (p<0.0001)

Table 13. June symptom and motion parameter correlations

SYMPTOM	VESSEL MOTION PARAMETER				
	Heave	***Mean heave rate***	***Max. combined seas***	***Wind wave***	***Significant sea***
Amount of sleeping time was short			0.56 ($p<0.0001$)	0.40 ($p<0.0010$)	0.56 ($p<0.0001$)
Sleep problems: ship motion		0.32 ($p=0.0099$)		0.33 ($p<0.0077$)	
Sleep problems: other	0.37 ($p=0.0021$)		0.62 ($p<0.0001$)	0.48 ($p<0.0001$)	0.64 ($p<0.0001$)
Sleepy			0.54 ($P<0.0001$)	0.36 ($p<0.0034$)	0.56 ($p<0.0001$)

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14. ABSTRACT

(U) Current oil and gas exploration requirements to exploit deeper water change the method of oil extraction. Floating Production Storage and Off-loading (FPSO) vessels are increasingly being used to operate in these fields where the environment can be very extreme. The Petro Canada Terra Nova Floating, Production, Storage, Offshore vessel (FPSO) is the first of its kind built for operations on the Grand Banks at the Terra Nova field and is the first to operate in Canadian waters. The crew on these vessels is expected to operate for as long as possible under extreme weather conditions within certain safety margins. Seasickness and its after-effects, motion-induced fatigue and motion-induced interruptions remain a potential threat to crewmembers at sea. Understanding the incidence, severity and the effects of seasickness on performance, can improve effective scheduling and task assignment. This survey attempts to (1) define the incidence and severity of the symptom complex of seasickness, motion-induced fatigue and task performance problems encountered on the Terra Nova FPSO vessel and (2) to examine correlations (if any) between FPSO vessel motions, seasickness, motion-induced fatigue and task performance, towards the development of recommendations to provide operations guidance to ameliorate seasickness and improve comfort and performance in the environment described above. A questionnaire-based survey of motion effects including sleep problems, symptoms and severity of seasickness and task performance was administered at various times during 3-week offshore shifts. Ship motion data provided for this analysis was based on data gathered from the helideck (at the bow of the FPSO vessel) motion analysis and was provided by the radio operator from the FPSO Offshore Installation Office. Based on 911 questionnaires returned, problems reported for sleep disturbance and motion sickness symptoms were slight to moderate. However, the correlation between sleep disturbance and ship motion was relatively high. January has the highest correlations among pitch, roll and heave motion with complaints of seasickness. Task performance problems such as loss of concentration, decision-making and memory disorders and task completion problems were observed. There appeared to be no apparent habituation among subjects who participated in more than 2 shifts offshore. It is apparent that the number of safety, health and performance issues increases with the deterioration of weather condition. This data serves as a preliminary assessment; direct measurement of the FPSO vessel motion and a longitudinal study through the winter months is required to substantiate our findings.

(U) De nos jours, l'exploitation pétrolière en mer se fait à des profondeurs de plus en plus grandes et les méthodes d'exploration ont changé, notamment avec l'utilisation des navires de production et de stockage de pétrole au large ou FPSO (de l'anglais Floating Production Storage and Off-loading) qui exploitent des champs pétrolifères où les conditions environnementales peuvent être extrêmes. Le navire FPSO Terra Nova de Petro Canada est le premier navire du genre à être construit pour l'exploitation du champ pétrolifère Terra Nova des Grands bancs et le premier à naviguer dans les eaux canadiennes. On attend des équipages de ces navires qu'ils travaillent aussi longtemps que possible dans des conditions climatiques extrêmes à l'intérieur d'une certaine marge de sécurité. Le mal de mer et ses effets secondaires, la fatigue attribuable au mouvement et les interruptions causées par les mouvements du navire représentent des menaces potentielles pour ces équipages. Une meilleure compréhension de la fréquence, de la gravité et des conséquences du mal de mer sur le rendement devrait permettre de planifier et d'assigner les tâches plus efficacement. La présente étude a pour objet (1) de déterminer la fréquence et la gravité de l'ensemble de symptômes associés au mal de mer, à la fatigue due au mouvement et aux problèmes d'exécution des tâches rencontrés sur le FPSO Terra Nova et (2) d'examiner les corrélations (le cas échéant) entre les mouvements des FPSO, le mal de mer, la fatigue due au mouvement et l'exécution des tâches, en vue de préparer une série de recommandations qui pourraient servir de guide dans l'élaboration d'un plan d'opérations visant à réduire les effets du mal de mer et à améliorer le confort et le rendement des équipages dans les conditions environnementales susmentionnées. Un sondage basé sur un questionnaire portant sur les effets du mouvement sur le sommeil, les symptômes et la gravité du mal de mer et l'exécution des tâches a été effectué à divers moments dans le cours d'une période de travail de 3 semaines en mer. Les données sur les mouvements du navire recueillis pour cette analyse reposent sur une série de relevés faits sur la plate-forme d'appontage de l'hélicoptère (à l'avant du FPSO) et transmis par l'opérateur radio aux bureaux des opérations offshore de la compagnie. À partir des 911 questionnaires retournés, on a appris que les problèmes associés aux troubles de sommeil et aux symptômes du mal des transports pouvaient être qualifiés de légers à modérés. Par contre, la corrélation entre les troubles de sommeil et les mouvements du navire était relativement élevée. Le mois de janvier a connu le plus important taux de corrélation entre

les mouvements du navire (tangage, roulis et pilonnement) et les plaintes associées au mal de mer. On a relevé plusieurs problèmes d'exécution et de réalisation des tâches, notamment au niveau de la perte de concentration, de l'indécision et des troubles de mémoire. Il ne semble pas exister de phénomène d'accoutumance parmi les sujets qui ont participé à plus de deux périodes de travail en mer. Il est apparent que le nombre de questions liées à la sécurité, à la santé et au rendement augmente quand les conditions climatiques se détériorent. L'analyse de ces données tient lieu d'évaluation préliminaire; il faudra prendre d'autres relevés de mouvements directement sur le FPSO et faire une étude longitudinale échelonnée sur tout un hiver pour vérifier nos conclusions.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Seasickness; performance; FPSO Terra Nova; ship motion

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